Synopsis

Ph.D in Resource Management

Trendsetting an Ecosystem of Resource Recovery and Value Addition in Sustainable Household Waste Management Applying a Systems Approach Model in In-Situ Hydroponics

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INTRODUCTION

Mother Earth has been drawn into a precarious condition for which the entire human race has to shoulder responsibility. Human beings and their advertent and inadvertent efforts have led to irreversible consequences ultimately projecting achievement of the **concepts of sustainability a question mark.** Rationale in using and conserving natural resources through sustainable endeavours alone can support future generations to benefit from the same resources that human kind enjoys today. It is high time that the present generation realizes safety, health and well-being are fundamental rights of all generations and it is them in turn to ensure proper and sustained resource access to their progeny. Hence adoption of smart, novel, innovative techniques both in usage and conservation of the resources, specifically **home-level wastes** is felt highly imperative.

Ways to maintain and endure natural resources for survival is the basic concept underlying sustainability. Misuse and misappropriation are highly dangerous to safeguard depleting natural resources, which has to be curtailed at any cost. Even a temporary deficiency of those indispensable survival resources can never be imagined of. **Water is such a depleting survival resource existing now.** Unsustainable methods of usage of this resource, environmentalists globally feel, can be the bone of contention for the next world war. Consuming public should never become a party to it. Natural resource utilization, waste and the enormity of non-biodegradable plus the **beneficial recoverable wastes** that go into the disposal stream emerge both as environmental pollutants and as global management concerns, while parallelly causing harm for human beings, especially in the long run**. Identification and management of wastes, waste water and organic waste** to be specific receives **premium attention**. The role of stakeholders, households in particular is found imperative to tackle the issues.

In the symbiotic relationship which exists between nature and human beings the dependence of the latter on the former for accomplishing personal needs and goals stands undisputed. Nevertheless, the problem now is with due respect to modern technological interventions in society- the **transformation of consumer's necessary needs into acquired needs**. In the name of technological advancements, people have started exploiting all vital resources, including air and water. As a result, the resources get depleted, get polluted with use and causes changes in the original composition of the resource thus used. The best example is water. Indiscrete generation and disposal of **waste water** has caught the attention of environmentalists as a major causal factor for environmental degradation as well as **resource waste**. This may sound complex. Breaking the complexity by reviving at least their near environmental condition becomes the **civic responsibility** of all people, especially every household. Evidently **management of resources post-consumption** through reuse, recovery and reclamation by households/ families within their ecosystem gets prioritized for conservation

endeavours. It is not just the wastewater they dispose, but also includes **organic wastes** that can be safely recycled. SDGs, in particular SDG 6 highlights commitment by each and every stakeholder on these issues. Through their personal involvement to conserve, recover resources from used resources, human beings commit to maintaining their personal family ecosystem and near environment free of pollution and degradation.

NEED FOR THE STUDY

Considering water as the elixir of life, a common public and environmental good, is also a human right, the sustainable use and management of which overrides all other perceptions about the resource. Effective management will mean tackling neglected issues such as water wastage which is estimated very high; common operational dysfunction, unethical practices, poor accountability, and lack of awareness and irresponsive behavior of consumers are a few reasons cited. Above all, **wasting water and further wasting of the wasted water**, a misrepresented /misplaced resource gains significance here. This happens mainly in the pretext that water has to be rendered safe to ensure safety and sanitation to maintain good health – the concept of **WASH** (**Water, Sanitation and Hygiene** concept).

- In the attempt human beings **purify drinking water (supply water) using various techniques even at home-level**, in the process where comparatively multiple volumes of water (**retentate**/discharge/reject water) are rejected without any beneficial use; almost a **1:4 ratio** especially from point of use purifiers.

- Another important **waste of inherent resource value is organic waste** from the kitchen. Anjum *et al.,* (2019) report that on an average, a household produces about 1.5Kg of solid waste per day out of which about **one-third is organic waste**. Such wasted resources from even a modest kitchen that get disposed as useless are yet another issue affecting health and sanitation of the households.

These two wastes, especially the huge daily volume of waste water from purifiers (retentate) pose a threat to sustainable living and the world at large.

According to Brondizio and Chowdhury (2013), the human - environment relationship at the local level is in itself a multilevel process and interactions between these two systems therefore should start from home- level environment warranting changes to be made fundamentally from the home-level (micro-level).The

Box. (1). THOUGHT – PROVOKING GLOBAL GOALS WHICH MOTIVATED THE STUDY

1. The Global Launch of the **UN World Water Development Report 2017 "Wastewater: The Untapped Resource**"
2. Chapter 16 "**Water reuse and resource recovery**": a clarion call for all stakeholders to act as silent partners to promote and upscale a good practice
3. **Waste = Food Concept** which encouraged considering **Retentate and Organic Waste as Key Resources from Family Ecosystems**
4. **'WHO' on wastewater reuse: to increasingly recognize waste water as a resource**
5. Academic interest: The **Talloires Declaration** on sustainability
6. Sustainable Development Goal number:6: stakeholder participation "**Ensuring availability and sustainable management of water and**

management of wasted resource at the household level, therefore, is the **need of the hour**. Over and above these facts, **homemakers need to be made aware of the wastes, they indiscreetly throw away, which really are misplaced resources.** Adoption of easy-to-handle, eco-friendly and cost-effective ways to manage these wastes for beneficial reuse which should follow, evidently receives priority here. In the process, households should facilitate creation of a clean, hygienic near environment, while exercising a best practice of recovering the inherent resource value of wastes. Above all this is an indigenous waste management system which can be adopted in a micro-environment of the family ecosystem. The motivating factors prompting taking up the study are also presented in the Box (1). Another significant factor is that **published research studies on repurposing retentate** (from large scale RO purifiers, industrial/institutional purifiers) though are available, **the practice executed with retentate from domestic RO purifiers is a felt lacuna, which also prompted taking up the study**. Especially such a study has scantily been reported in home-level studies.

ASSUMPTIONS AND ARGUMENTS PUT FORTH

As per systems approach concept in resource management, a family is a **personal** and **micro environment** encircled within the macro environment. There exists a constant interaction between families and their near environment which qualify them to be called as ecological systems or **ecosystems.** Almost all family resources, especially **natural resources**, originate in the macro environment and families' change them into forms they find fit for consumption. During such transformation and consumption processes they contribute directly to elevated waste levels. Anything that enters into this family ecosystem becomes an **input, including wastes** that get generated out of human use and consumption.

Micro-sustainability tenets focus on small environmental actions to result in large environmental impacts. Hence, its principles center on individual efforts, behavior modification, attitudinal changes in individuals and community, encouraging sustainable changes as 'change agents' fostering positive actions in their own inside spheres of influence addressing and practicing the concepts of the three / six R's. Though other household wastes find their way to community bins or drainages, **two wastes over which homemakers can have access to and can try to reuse or recycle is the retentate from purifiers and organic wastes from kitchen. Homemakers need to abrase themselves to access and recycle them for repurposing which can be a stepping stone to home-level micro - sustainability**

As it is rightly said, "Charity becomes at home", comprehending the wastes generated in the family ecosystem (**input)**, becoming sensitive and devising appropriate methods (**throughput**) to manage them for productive use (**output)** can emerge as a **trend setting systems approach model in household waste management provided low- cost technology of home-level hydroponics can be attempted.**

With this backdrop the study was streamlined to include a household survey on water consumption, estimation of water wasted as retentate, do trial experiments in in-situ hydroponics involving coir pith as substrate and retentate (for hydration) for raising seedlings/ plantlets from

seeds, test products for quality, create awareness among homemakers on all such concepts and making them involve religiously in trying them in their personal spaces, create micro-biophilic spaces and enjoy the benefits of their waste management acumen. Based on this premise the following objectives were set for the study.

OBJECTIVES OF THE STUDY

- **Estimate wasted resources accessible to homemakers (retentate and organic wastes), make them aware of and confirm their quality for safe use and their inherent resource values for beneficial reuse**
- **Examine prospects for recovering and repurposing 'accessible wastes' for "sustainable use - reduce and – reuse" adopting eco-friendly low-cost technologies of value addition of wastes and home-level hydroponics from seeds**
- **Envisage home-level hydroponics in the built environment from an eco-ergonomic viewpoint by raising safe edible plants using recovered resources from select household wastes and trend-set the concept of biophilic kitchen garden among stakeholders**
- **Instill home-level waste management as in -roads to good housekeeping and micro-sustainable living in family systems and enthuse homemakers to perform as pro-active change agents**
- **Draft a systems approach model for "home-level micro C2C waste management module" addressing the best practice**

SCOPE OF THE STUDY

Environmentalists have come up with several retrofitting concepts such as RRR, circular economy, sustainability, eco – consciousness etc to tackle the environment cum waste management problems. Reclamation of wastewater generated from domestic RO purifiers (retentate) and kitchen waste using a method called biological reprocessing receives special address in sustainability discourses, as disposing both in the near environment can pose an environmental hazard to human well-being plus waste of natural resources.

Ipso facto, this study had explored and executed **indigenous home-level waste management** practices that could be undertaken by homemakers **to recover inherent resource values in the two accessible wastes and reuse/ recycle** them not only for **beneficial reuse** but also design of personal spaces which can provide both real and psychic income to the families concerned.

DESIGN OF THE STUDY

The design of the study involved five sequential stages and their corresponding seven phases.

- **Stage I: Household Survey:** This included two household surveys targeting urban (25 families for 10 wards each from all five zones namely Central , East , West, North and South) and Rural households (12 families each from East , West, North and South zones) in

Coimbatore, Tamil Nadu, India , for conduct of the study adopting purposive sampling as only those households using Point- of – Use water purifiers were selected for the study mainly to decipher the quantum of wastewater (retentate) rejected during purification and the ratio of purified water (permeate) to retentate obtained. The interview schedule administered requested details on purifier brands, consumption pattern and the volume of wastewater discharged, details on wastewater reuse and awareness about the hydroponic technology.

This enabled estimating the retentate wasted from these households cumulatively which is an example of indiscriminate waste of a national resource occurring from recovery for human action. As only a negligible proportion reported of reusing the wastewater for cleaning etc and were scarcely aware of hydroponic technology the next stage was taken up.

- **Stage II - Hydroponic trials as a waste management strategy:** This included phase II of the study where, hydroponics experiments were done as a pilot study on raising plants – fodder in trays, seedlings on pro-trays and microgreens in small throw away containers - **reusing the retentate**. All the experiments were carried out in a selected sample house in a peri-urban area located in the west zone of Coimbatore and one using Brand A purifier (Rural households for raising fodder and urban household for other hydroponics trials). These experiments were repeated to ensure the quality of the retentate and feasibility for raising seedlings of five specific edible plants, and to establish retentate is safe for reuse in hydroponics. Quality of retentate was tested and found safe for reuse.
- **Stage III - Envisaging home-level circular economy in household waste reuse via biological reprocessing-based kitchen garden:** This stage encompassed two distinct phases. The third phase dealt with identification of inherent resource values in retentate and organic wastes for recycling through value addition. The fourth phase saw to fruition conduct of in-situ hydroponic trials with eco-friendly home-made concoction – the experimental nutrient solution. Comparative analysis was also done with the control sample for which nutrient solution made using commercial vermicompost and retentate was used.
- **Stage IV – Trendsetting micro-biophilic spaces for stakeholder participation:** Propensity to raise air purifying plants indoors reusing the retentate for hydration was attempted, especially to create micro-biophilic spaces with available and indigenous materials. This way of practising environmental technology was aimed to create prospects for micro-sustainability and thereby, achieve behaviour modification in wasting, attitudinal changes and eco-consciousness among select homemakers. And in the next phase, the stakeholder's involvement through knowledge sharing on practicing hydroponics was made and the attempts were found highly successful.

  This phase was conducted with goodwill to share the knowledge gained through the study and also to reclaim the kitchen waste, RO wastewater productively for the well-being of a few selected households. Twenty homemakers (RO water purifier users) were encouraged to initiate biophilic spaces in their premises (built environments), adopting hydroponic techniques.

  During the early phases of the study, rapport was created with the selected homemakers, followed by knowledge sharing. The procedure for raising plants adopting

hydroponic techniques was demonstrated along with materials such as grow bags, seeds, plants and substrate (coir pith),to practice the same in their homes.

- **Stage V - Waste management strategy using systems approach model:** The final phase dealt with designing a strategy for eco-friendly, accessible household waste management applying systems approach model. With this as a base, it is hoped that prospects for upscaling several other household wastes can be thought of to tackle and manage wastes at the home-level itself.

SALIENT FINDINGS

A synoptic note on the salient findings of the study is presented under specific headings

I. Findings of the household survey:

Calculations based on which water is supplied for consumption.

As per IS-1172-1993, water requirement for domestic purposes for India is an estimated 135 LCPD (Litre per day per capita) in urban areas and 70 LCPD in rural areas under normal conditions. Based on this, the study revealed that the total water supplied to individual families in Coimbatore Corporation was a standard 135 LCPD. Accordingly, the proportion of water for drinking alone was fixed at 5 L out of 135 LCPD. The value though is 3.7 per cent, another aspect prevented supply of water on this score. As per NFHS (National Family Health Survey)-3 reports, Tamil Nadu records the lowest average household size, namely 3.5 per family. Based on that only, water is being supplied. Therefore, the supply in toto was found to be comparatively lesser. Evidently, water allocated for every family during each distribution day was only 17.48 L, which had to be used till they received the next supply. Unfortunately, during the period of study, the duration was every 14 days. Despite each family receiving 472 L, it was found as per allocated supply it was only 437.06L per supply. Within this, water allocated for drinking alone per family per supply was 17.48L. In rural areas, the proportion of drinking water allotted was 3 L out of 70 LCPD. Based on this derived value of 4.29 per cent the water supplied, per family during each distribution day, was only10.5 L. To ensure safety, health and well-being, all the samples were found to use purifiers among which **Brand A** was found to be most popular Zone-wise and the preferred one among Central, North and West zone samples. Brand wise 50 families out of 125 urban families and 16 out of 48 rural families used Brand A purifiers.

- Mean retentate generated by the purifiers was to the tune of 3.44 to 3.58 L and 3.28 to 3.63 L for every L of permeate purified in urban and rural areas respectively. Those using Brand A obtained least permeate. Apparently, both zone and brand wise study proved that use of point-of-use purifiers incurred waste of water to the tune of thrice to four times the water purified.

b. Cumulative retentate wasted from households: During each supply from the selected urban households alone, more than 12147 Gallons (45985 L) got wasted, while from the rural households it was a total of 2408 Gallons (9118 L). The study revealed that the samples used the entire supply for drinking itself. Hence the zone wise and brand wise retentate wasted from

cumulative supply also revealed a 1: 3.52 permeate to retentate ratio in urban and 1: 3.45 L in rural households.

c. Zone wise and Brand wise data on permeate availability per capita per supply:

Zone-wise water availability per family per supply (every 14 days) was very less, only approximately 34L in urban households and 17.5 L in rural households. From that, permeate available /capita/supply was lamentably low – **just a little more than one liter.** All calculations led only to one point, namely the water supplied, allocated and available in purified form / capita/supply was only **one liter**, about which none of the consumers were aware of. Unfortunately, gallons of water got wasted from each household using a point-of-use purifier.

In urban area, brand wise data on water available per capita per day (every 14 days) was 8.40 -9.81L, while, permeate Vs retentate accountable per capita daily in a 14-day duration supply was 2.11:7.70 L (Brand A). The Brand A purifier was found to record maximum retentate generation. The mean retentate accountable per person per zone using Brand A purifier recorded the maximum in the West zone – 17.54 L.

In rural area, brand wise data on water available per capita per day (every 14 days) was 2.69 - 7.29 L, while permeate Vs retentate accountable per capita daily in a 14-day duration supply was 1.24: 4.59 L maximum again from Brand A. Rural households too using Brand A recorded the maximum in the west zone to the tune of 21.33 L.

Phase II: Reuse of retentate for Hydroponics using seeds: As the retentate wasted very high, the next stage was to find out if they can be used for beneficial use, especially in-situ hydroponics using seeds. Hence, this part of the findings is presented under:

1. **Findings of the feasibility studies:** The main objective of this study was to test the feasibility for growing seeds (germinating) hydroponically in home-level situations using retentate for hydrating the seeds. The findings are explained in the following sub headings.

- **Ingress water / Point – of – Use water** –Untreated water let in to the purifier
- **Permeate** – Purified water obtained from the RO unit
- **Retentate** – Wastewater discharged from the RO unit

- **Raising Fodder Hydroponically:** The scarcity for green fodder as a major constraint expressed by rural households for their dairy related activities, prompted choosing fodder for hydroponics trials using retentate and permeate for comparison. Findings showed growth potential of the seeds soaked in retentate was comparatively faster with good dense mat formation and shoot growth was achieved in just nine days. Growth potential was poor in permeate grown sample even after nine days.

Hydroponics is the technique of growing plants in water or nutrient solution without soil (Dharm, 2013)

- **Trials on Pro-tray hydroponics:** Five plants of prime importance selected for propagation trials in pro-trays were coriander, fenugreek, amaranth and tomato with seeds and mint alone with cuttings. Having opted for hydroponic technique, soil was not used. Instead, coir pith (waste from coir industries) was used as substrate. The findings brought to light that edible plant

seedlings could be successfully grown adopting hydroponic technique and reuse of retentate, motivating trials in raising microgreens too.

- **Microgreens:** Greens such as coriander, fennel, fenugreek and mustard were grown from seeds sown in coir pith and hydrated with retentate. Further procedure for analyzing presence of toxic elements and other elemental content if any in the microgreens using FESEM EDAX tests was taken up. The test findings showed that these greens had a store of all five major essential minerals, almost nearing NIN standards. As they will be consumed only in lesser quantities, it is assumed that they can very well act as functional foods and nutrient supplements.

2. **Outcomes of experimental studies on hydroponics:** This aspect of the study is explained under the following sub headings:

a. Testing quality of retentate for safe reuse in edible hydroponics: Water samples of ingress water, permeate and retentate were given for quality analysis. The general parameters of the tested water samples showed that the values for total alkalinity and hardness in ingress water and retentate was found to be less than the acceptable limit. The other parameters like BOD, COD, Bicarbonate, Electrical Conductivity (EC) and TDS were within acceptable norms. The result also showed the presence of some essential elements required for plant growth.

These findings proved all three samples, especially retentate to be safe for plant growth, as they displayed presence of toxic elements too to be well below detectable limits.

b. Prospects for raising edible plants hydroponically on comparative basis: This phase focused on repeating the experiments done in feasibility studies to ensure their practicality for home-level in-situ hydroponic trials to grow nutrient rich greens and vegetables and also test the efficacy of retentate in raising specific plants. These experiments were conducted in controlled conditions choosing control vs experimental samples. Control samples were raised in point of use water and experimental samples in retentate.

i. Hydroponic Fodder in controlled condition: The first experimental study was on growing fodder from two select millets, namely maize and jowar. Procedure followed was the same as before, but materials used were measured and used, including hydrating water and was raised in an indigenous mock green house to ensure temperature and humidity conditions. The growth milestones of Maize and Jowar was recorded and compared with an authentic source. Though they could not meet the stated standard growth potentials, the experiments proved that the fodder seeds could be grown adopting hydroponics successfully. In both, the growth potential in experimental samples was better than control sample. A comparatively dense sprout mat formation could be achieved using retentate. For every one kilogram of seed, 2.25 kilogram of maize and 2.21 Kg of Jowar sprout mats was obtained within a short period of nine days, proving retentate can be safely reused or **repurposed** for obtaining an edible product.

ii. Prospects for seedling growth from seeds in pro-trays: Initial experiments proved retentate to promote shoot and root length in coriander, germination in tomatoes and amaranthus. Hence for raising under controlled conditions (in naturally ventilated poly house) all five greens namely coriander, amaranth, tomato, and fenugreek seeds were used. Mint alone was used as cuttings. In amaranthus, mint and fenugreek, growth spurt of experimental samples was comparatively faster

and good than in control samples. In coriander and tomato, growth milestones of control samples were on par with the experimental samples. Leaf emergence and growth in fenugreek and mint was commendable in experimental samples. It was gratifying to record **retentate to promote germination of select seeds** and their root and shoot growth leading to appreciable seedling growth in them. Germination rate was approximately 98-100 per cent in all seeds.

iii. Yield and nutrient content of micro greens raised in controlled conditions: Five common greens used in Indian homes namely coriander, fennel, mustard, fenugreek and amaranthus were chosen and raised as control and experimental samples to aid in comparison. The procedure and method remained the same as in feasibility study, but for, doing trials using three sets of control and experimental samples each simultaneously. All the samples were left to grow for 12 days, as the feasibility study proved that microgreens reach ready - to - harvest stage within 11 days. The findings showed fennel, coriander and mustard to have showed better root length in experimental, while the same was good in control samples of fenugreek and amaranthus.

Nevertheless, the seedling length (Root + Shoot length) reflected only root length findings. Considering experimental sample, except for coriander all the other four seedlings recorded more production of microgreens in terms of fresh weight. With regard to dry weight of the microgreens fenugreek and mustard showed commendable output in experimental group.

The experimental study proved that retentate can be successfully used to raise microgreens. Being an edible plant, it was found imperative to test them for human consumption. Dried samples of all the microgreens were tested for their mineral composition and presence of toxic elements using FESEM EDAX test. All samples (both control and experimental samples) revealed the presence of minor elements like Ca, Mg, K, P, Zn, Mn, Al and Na. The samples were compared with NIN standard composition. The findings showed that the studied experimental sample, especially had macro nutrients like Ca, Mg and K. which can supplement human mineral requirement. Further they can be grown even in window sills and balconies where homemakers can easily raise, maintain and use.

Inferences drawn from the study pointed out that retentate can be used successfully to raise microgreens and Output can be enhanced provided the nutrient quality of the retentate can be fortified.

iv. Raising seedlings to plantlets hydroponically in Growbags: From the cues obtained from the previous trials, it was decided to increase the perimeter and rooting surface by increasing the size of the growing surface, specifically a standard grow bag. Five seeds raised in microgreen trial experiments were tried in these experiments too. Fennel alone was substituted by tomatoes. The findings revealed that the growth potential of both root and shoot in experimental sample was found to be comparatively longer compared to control sample in all the seedlings planted proving again retentate promotes plant growth and can be used to raise home – level kitchen garden even in small spaces available in a kitchen. The experiments done and the outcomes proved that retentate could be successfully **repurposed as growth promotors** of plants adopting the eco – friendly, low – cost hydroponic technology. Another significant finding was that though retentate was used to hydrate seeds/ seedlings/ plants in all these exercises , still a family

would have stock of retentate, because all the experiments done till this stage used up only little amount of retentate - a finding highlighting minimum as well as **an optimal reuse of the resource**.

Stage III: Envisaging home- level circular economy in household waste reuse through value addition

Phase III presents the recovery of resource from accessible household wastes and value addition of retentate and organic wastes enabling a home – level circular economy – that is, using, recycling and reclaiming resources from waste for reusing them again in another form. With this backdrop, vermicompost was first made and then a nutrient concoction, mixing vermicompost with retentate was attempted. The nutrient solution thus formulated was applied on select seeds in pro-trays and later in growbags (under Phase IV), for raising flowering plants, herbs and edible plants.

a.Value addition of wastes: This aspect of the findings is explained under the following sub headings:

i. Value addition of wastes through vermicompost : All households generate certain wastes which are accessible to the homemakers alone. Three such things specifically related to this study included retentate, spent coir pith and organic wastes from kitchen. Daily collection was weighed and recorded. Retentate over and above that used for other purposes as explained earlier being available, was used to produce vermicompost with organic wastes accessible from kitchen and the spent coir pith obtained post experimental studies done in Stage II. Before that spent coir pith was tested for nutritive value and was found safe for reuse/recycling.

Only indigenous eco-friendly materials were utilized for conversion to value added product from waste namely vermicompost. On an average 5.73 ± 0.62 kilograms of vermicompost was harvested in every batch comprising two months from a small household where the experiment was conducted. The conversion rate of organic waste to vermicompost was 46 per cent. The report of the laboratory analysis on experimental sample of vermicompost produced combining the three wastes, indicated the presence of essential elements at adequate levels, much required for plant growth. Hence, homemakers can adopt this technique to recycle the wastes within their premises and create **a closed home-level circular economy**. That way anybody can recover the inherent resource value in the wasted resources, add value to them and use for beneficial purposes.

ii. Value addition of vermicompost to nutrient solution: Nutrient solution was prepared using a feasible formula of organic inputs and several trials. The **nutrient solution (NS)** was prepared for raising plants hydroponically. NS using an organic matrix comprising homemade vermicompost (Experimental sample) and retentate (NS 2) was prepared. Similarly following the same procedure NS 1 was prepared (Control sample) using commercially available vermicompost from an authentic institution adding retentate. Both the solutions were tested for their nutrient contents in a reputed Lab, in their concentrated form. They were diluted in different concentrations for use in watering plants. They were found to be safe and good for garden and

edible plants. The nutrient solution (NS2) was prepared in varied concentrations like 0.5%, 5%, 10% and 20% from the basic organic matrix – retentate combo to be used for foliar application on plantlets. For comparative purposes, same plants were raised in NS 1 as control sample.

Phase IV: In- situ hydroponic trials with eco – friendly control Vs Experimental Nutrient solution: This part of the study dealt with the following experimental studies on a comparative basis. Main delivery mechanism of nutrients to the plants was through retentate or home-made nutrient solution in varied concentrations. In-situ experiments in hydroponics which followed focused on raising herbs, flowering plants and edible plants. One herb (Sweet basil) and two flowering plants (Marigold and Cosmos) were tried using the nutrient solution, as these plants were commonly used ornamental plants and have several pharmaceutical properties.

a. Potential of Homemade NS to promote Herb and Flowering plants: Both NS 1 and NS 2 in 0.5% concentration failed to promote growth of the selected herb and flowering plants. Both the solutions in 5% concentration again failed to promote cosmos and marigold but aided sweet basil growth. In 10% concentration NS 1 showed stunted growth but promoted sweet basil growth, while NS 2 was very efficient to help growth in all the plants till flowering. It could be concluded that the home - made nutrient solution (NS2) in 10 % concentration can be successfully used to raise these select herb and flowering plants in the home environment.

b. Potential of the home-made NS to promote growth in edible plants: In this phase two edible plants were chosen for the experimental study namely, green chilly and tomato – two indispensable spice providers used in all Indian homes.

The trials were done on a comparative basis, using home-made NS 1 (in different concentrations) as experimental sample with the control sample. Pro-trays were used to germinate seeds and growbag to grow plantlets for the transplanted seedlings as control and experimental sample. Both, the pro- trays and growbags were placed in the naturally ventilated polyhouse structured for the purpose. The seeds were sown in pro-tray and seedlings were transplanted after 28 – 30 days. In these experiments the control sample was grown in soil (not coir pith), while experimental sample was in coir pith. Hydration in both was with respective nutrient solutions.

The findings of the germination potential of the green chilly in the said treatments (NS 1 and NS 2) showed that the germination and growth in control sample was quite slow. In both tomato and chilly, samples germinated in NS 2 in 10% concentration, performed better showcasing comparatively faster and commendable growth even above NS 2 (20 %) concentration. Germination rate also was almost 100% in the samples treated with NS 2, both in 10 and 20% concentrations.

In chilly plant, the shoot length of green chillies hydrated with NS 2 (20%) showed commendable spurt than those in the other two. It was clear that NS2 (10%) was a good root promoter and the same nutrient solution in 20% concentration highly favoured shoot length and yielding in green chillies. It was disheartening to record there was no yielding in control sample and the plants just wilted slowly after flowering stage. The plantlets grown in home-made NS

(both the concentrations) gave good first yield and much of a difference was not noted between concentrations. First yield of the chillies was 48g in NS 2 (10 %) and 51g in NS 2 (20%).

i. In tomato, the plantlets raised in NS 2 gave the first yield in 15 weeks (till ripened stage), which was on par with farm harvest days. The plantlets grown in home-made NS (both the concentrations) gave good first yield but showed good difference as it was only 53 per cent of the yield obtained in NS 2 (20%) samples. First yield of tomatoes with NS 2 (10%) was 148 g and with NS 2 (20%) was 277 g. These findings prove that the home-made NS 2 in the 20 % concentration definitely can provide for nominal requirements of the produce for small households. Definitely the exercise assures that it is a **viable home-level waste management cum beneficial one**. It is thus a proven example for management of accessible wastes for beneficial reuse. Next step evidently was to ensure that the products harvested were edible - safe and are also appreciable in their elemental (nutrient) content.

ii. Though the experimental samples were not found to be very rich in their trace element content, it was encouraging to record that they had the major ones (Na, Mg, K, Ca, etc) as published in the guidelines in small amounts. As the values have been derived out of dry weight, probably in their fresh forms the tomatoes and chillies would provide additional inputs. A significant finding was that the samples did not have any toxic elements and hence were safe for consumption. It can be concluded that preparing this NS as a viable management measure of accessible waste and recovering resources for growing chillies and tomatoes definitely is a **wealth from waste measure**, where any homemaker can help her selves and the community at large in the long run. It was gratifying that the "value added" recovered resources emerged as viable nutrient solution for use in in – situ hydroponics. This has cut cost on buying commercial nutrient solution for raising hydroponic plants. Definitely, this is a **micro – sustainable** endeavor in home level situations. Having a micro biophilic kitchen garden around her definitely adds to her psychic income. However, preparation of vermicompost and nutrient solution as by- products of resource recovery cycle had proved successful.

Stage IV: Trendsetting micro-biophilic spaces for stakeholder participation: This aspect of the findings is presented under two phases: V and VI. Phase V dealt with creation of micro-biophilic spaces and trending hydroponic air purifiers.

a. Raising other plants adopting hydroponic technique: In this phase, the trial experiments were conducted to propagate other plants hydroponically using retentate from cuttings, bulbs and leaves. Attempts on portulaca in several colours was a treat in the balcony. Among edible bulbs/tubers, turmeric, ginger and potato were tried. Turmeric and ginger was successful, but potato, though grew well did not yield. Rain lily bulb chosen from flowering plant grew well and had blossomed too, again adding aesthetic appeal to the space. Coir pith as substrate and retentate was used for propagating all plants.

Leaf propagation in Jasmine attempted was successful with good root formation and beyond. These are proof enough to say that decorative plants, edible tubers, herbs and aromatic plants could be raised hydroponically in small areas, and households can aesthetically create micro-biophilic spaces for ensuring their health and well-being adopting hydroponics

technique using retentate. Need not even use expensive containers, **indigenous materials would suffice – enabling another waste management measure.**

b. Propagation of Air purifying plants in indoor spaces: Air purifying plants was raised hydroponically in coir pith and retentate as experimental sample on a comparative basis with control (Soil and retentate). Using a real time air quality monitoring device, the values of all the parameters such as Total volatile compounds, particulate matter 1.0, CO_2, Formaldehyde and Air quality Index were monitored.

The indoor air purifying plants chosen for growing were aloe vera, spider plant and Money plant. These plants showed not only visible growth, but also proved that they could purify the air, especially the values recorded at night before occupation, in the morning and later in mid noon which showed appreciable changes in the interiors compared to control samples and both the samples kept in exteriors. The findings proved that retentate hydrated air purifying plants could be successfully grown in interiors to achieve appreciable air quality too. The inmates of the houses where these plants were grown were highly satisfied with the findings and they continued growing them in their houses.

c. Creating Micro biophilic spaces: A few micro biophilic spaces were created using household indigenous materials available. These models included tower garden (open system), Micro Vertical Garden unit using waste bottles and Mimicked Nutrient Film technique model (both closed systems). These were apart from the microgreen and growbag plants raised hydroponically. The plants raised were Portulaca (ornamental) and edible greens like mint, coriander, amaranthus, fenugreek and palak. These biophilic spaces were easily portable and made up of non-biodegradable waste materials, like used-up wire mesh, shade net, coir pith (as a substrate), perforated pipe and bucket, bubbletop water bottles, small waste bottles etc. (all ready-for- throw materials). The micro-level vertical garden unit and mimicked NFT were placed in one of the sample houses to recycle the retentate discharged. Plant growth was good in all biophilic spaces fabricated rendering treat for human senses – flavour, taste and beauty. All such experiments have proved to advocate for a low-cost technology (hydroponics) using wastes as resources and emerge as trendsetters for creation of micro – sustainable environments in any households.

According to Delfin.*et.al.*, (2017) in open system hydroponics, any excessive irrigation is allowed to go to waste, and it is not recycled. In closed system hydroponics, irrigation drainage is captured and recycled.

Phase VI: Stakeholder involvement through knowledge-sharing on hydroponics: The findings are explained under:

1. Training an eco- conscious cohort of homemakers as trend setters: Knowledge sharing on creation of biophilic spaces using coir pith and retentate to the selected twenty homemakers and provision of basic materials definitely effected a positive attitudinal change in them to try out and emerge successful in this small-scale waste management endeavor. Only resource they had to put in was retentate from their RO Units. This prompted them to attempt to propagate plants within their premises. Periodical visits for monitoring plant growth was done. They were

enthused to monitor the day-wise growth of microgreens and the micro- biophilic spaces and share their experiences.

Furthermore, guidance to harvest and store them enabled use of microgreens in preparation of novel dishes. They agreed that they enjoyed sprinkling and garnishing a variety of dishes with them which added flavour and aesthetic appeal to the served dishes. Some samples had even dried and stocked them for future use. They had shared their dishes with family members, friends and neighbours and vouched well for their organoleptic qualities. As a major outcome of acceptance of the technology, one of the homemaker sample had installed a hydroponic vertical garden unit using indoor air purifying plants, flowering and herbal plants and also reusing retentate for watering on a periodical basis.

2. Knowledge sharing in an Institution: With prior permission, a model NFT unit was installed in the Institutional premise and a flowering plant (portulaca) and an edible green (Mint) were raised in this closed system hydroponics.

- RO discharge water was fetched from a purifier unit installed in a laboratory, which wasted 65 -90 L of retentate every day based on consumption levels and that water was recycled in the unit to grow plants. Oral demonstration was given to several interested students, staff and faculty who were attracted by the unit, day-wise growth of the plants and the sweet aroma. Growth of plants, placement of unit like a vertical garden coupled with the main objective, that is recycling of waste water and growing plants without soil was well appreciated. Many expressed desire to install one at home, save wasted water through recycling and benefit personally. Many even took the mint leaves home to add flavour and taste to the dishes they made and were appreciative of it. Such knowledge-sharing was all the more gratifying. This endeavour promoted not only recycling/repurposing for beneficial use, but also was psychologically satisfactory.

These success stories further proved that using in - situ hydroponics technology with retentate as water for hydrating, households can easily adopt **home level micro-sustainability measures of waste management** which further can project them as positive change agents (inside their sphere of influence) in the crusade to campaign for the R's concept (Reduce, reuse, recycle, recover, repurpose, reclaim) to tackle waste and conserve natural resources.

Phase VII. Waste management strategy using systems approach model

This aspect of the study was aimed at presenting a diagrammatic representation of waste as resources (for input), the low cost technology of hydroponics and the procedures (for throughput) and the benefits accrued for the family, community and world at large as outcomes (output).By streamlining the three concepts input, throughput and output, homemakers can easily bring in a 'micro – circular economy' within the family ecosystem advocating the principles of C2C – cradle to cradle concept. Through these endeavours the five objectives set for the study have been achieved.

- **Accessible household wastes (retentate and organic wastes) were comprehended for safe reuse.**

- **Low cost (appropriate) technology adopting in – situ hydroponics in different ways was tried to raise both ornamental and edible plants**
- **Inherent resource values of wastes were identified through quality testing and value addition for quality and recycling done**
- **Awareness among select homemakers to adopt the technology to practice the concept of Use-recycle- reuse, as good housekeeping and create an ecosystem of micro-sustainability within their sphere of influence (the built environment) was done. The select homemakers had emerged as trend setters and ambassadors for their micro - level mission.**
- **A sustainable waste management strategy for accessible household wastes applying systems approach model in in – situ hydroponics was thus drafted and found successful.**

SUMMARY AND CONCLUSION

Throughout the research period, the study aimed at recycling the accessible household wastes in a productive way through home-level waste management. The study proved that by practising home level appropriate technologies namely – hydroponics to upcycle wastewater to raise plants, circular economy concepts in preparation and use of vermicomposting and nutrient solution designing biophilic spaces with ornamental and edible plants - can contribute to a resilient environment which vouch for human well-being. The experiments on fodder, microgreens and vermicomposting if taken up seriously can pave way for income generation avenues especially for homemakers and also add to their psychic income.

With the upcoming demands for microgreens in chat corners and restaurants and saplings in nurseries, such homemakers can emerge as real trend setters, advocates for promotion of these techniques or appropriate technologies by becoming entrepreneurs or by initiating community level units. The study had thus enabled the following:

- Re harvesting lost (wasted) water from retentate
- Recover and repurpose inherent nutrient values in organic wastes for composting
- Energize primary consumers (family / homemakers) to trend – set in-situ hydroponic using household wastes.
- Think out of the box to produce vermicompost based nutrient solution using retentate.
- Evolve a systems approach model for sustainable household waste management, considering accessible wastes as inputs, process of transformation as throughput and benefits accrued as outputs.

The research study has been an eye-opener to identify a new waste (retentate) source and to try out novel methods of reusing the inherent resource in it, hitherto not published or as attempted earlier. It is hoped that the study can be germane for such other studies to follow.

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